A Comparison of Sea Ice field Observations in the Barents Sea Marginal Ice Zone with Satellite SAR Data

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***Abstract*- Routine sea ice observations of ice type, concentration and thickness were carried out during a microwave remote sensing validation campaign in the Barents sea aboard the US Coast Guard icebreaker Healy during October-November 2001. Ice near the edge was generally a near equal mixture of small to medium floes of thin first-year ice and approximately 2 meters thick multi-year ice, with large floes occurring deeper in the ice pack. These data are compared to estimates of ice concentration from several radarsat and SSM/I images to validate routine operational ice analysis performed at the National/Naval Ice Center in Washington, D.C. Observations of several different ice regimes observed in the field are compared to observed SAR backscatter characteristics. Results show that while some distinction between ice types can be made within the pack, near the ice edge unambiguous determination is difficult from SAR data alone. For the most accurate analysis of ice conditions from SAR in the marginal ice zone, the day to day evolution of the ice drift and growth should be monitored.**

I. Introduction

The central mission of the National/Naval Ice Center (NIC) is to provide routine operational analysis of sea ice conditions in polar waters. Of primary interest to the customers of NIC is the marginal ice zone (MIZ). Unfortunately, sea ice conditions are inherently inhomogeneous and highly variable in marginal seas, often making ice type identification difficult. RADARSAT synthetic aperture radar (SAR) data is relied upon heavily in producing charts of ice conditions. Within the pack, an experienced analyst can readily differentiate between ice types based on floe texture and radar brightness. Near the ice edge, however, small floe size and intermingling of several ice types in close proximity can lead to ambiguous visual clues.

In October-November, 2001, a sea ice research cruise aboard the USCGC Healy provided the opportunity to obtain shipboard observations to compare to simultaneous satellite data near the ice edge in the Barents Sea. We show that while RADARSAT can be relied upon to provide ice extent and concentration, ice type identification can be difficult near the edge. Passive microwave (SSM/I) data can provide supplemental information in some cases, but must be used with care.

II. Ice Conditions

Visual ice observations of ice type, thickness, and concentration were taken in the Barents Sea between approximately 30° and 10° east longitude and 80° and 82.5° N – generally within 100 km from the ice edge. Overall, 66% of the ice observed was first-year, young or new ice, while 34% was multiyear. Floes were typically several hundred meters across or less, and ice types were usually intermingled, often fused together in the same floe. First-year ice rarely exceeded 30 cm; Multi-year ice was 1-3 m thick. While new ice such as pancake ice was typically observed near the edge, much of the ice observed deeper in the pack was first-year ice.

III. Methods

Ice concentrations are compared for 15 locations for which RADARSAT imagery and field observations were coincident. Shipboard estimates are averaged as much as possible over a 25 km square area to provide the most appropriate comparison with both SAR and SSM/I observations. Discrimination of ice types in SAR imagery was performed using a backscatter thresholding technique to separate first-year and multiyear ice. This relies on the fact that first-year ice usually exhibits lower backscatter than multi-year ice [1]. Images were first corrected for variation of backscatter with incidence angle [2]. Because sea ice scatters anisotropically, the correction factor was arbitrarily increased by a factor of 2 to provide the best match to observations [3]. This correction was found to provide consistent results so that a dynamic threshold was not necessary. The most suitable threshold was found to be –15.5 dB, though its effect depends on the area of application (note that since RADARSAT scenes from the Tromso receiving station have not been absolutely calibrated, that this value is somewhat arbitrary). Prior to thresholding, a morphological opening [4] is applied to each image to filter high frequency speckle noise without altering the size of features. Results for each region are also compared to SSM/I derived concentrations from the NASA team and NASA team 2 algorithms [5].

III. RESULTS

Within the consolidated pack, thresholding provided reasonable discrimination between first-year and multi-year ice (Fig. 1). Discrete multi-year floes can be readily distinguished from the darker first-year ice, although the amount of first-year ice is underestimated somewhat due to bright returns along floe edges and refrozen leads. With this in mind, the amount of first-year ice (33%) compares reasonably well with nearby airborne observations (~%50). The NASA team algorithm estimates 34% first-year ice for this scene.

Despite the visual contrast between ice types, we note that the range of brightnesses in this image is of the order of 4 dB. Due to edge effects from increasingly small floe size, and the close proximity of varying ice types of small footprint this range decreases to almost nil as one approaches the ice edge, making discrimination between ice types impossible. Then, a threshold can only be used to differentiate between ice and open water. Fig. 2 shows a scene of ice that has most likely formed recently, yet exhibits a uniform, relatively high backscatter. Thresholding suggests that this may be multi-year ice; indeed, the NIC ice chart for October 29 indicates predominantly multi-year ice in this area. However, analysis of ice drift indicates that this is most likely consolidated pancake ice that formed from a large frazil/grease ice slick observed a week earlier. The calculated concentration (80%) compares well with the NASA team algorithm which indicates 73% first-year ice.

Within the operational area of the Healy, floes were generally much smaller than in the above examples. This effectively prevented any ice type classification by backscatter or texture. Observed and SAR-derived ice concentrations compared very well in most cases (Fig. 3). The exceptions are one location at the edge where the ice was predominantly in belts and strips of thin ice, and one location (indicated by the arrow) where the ship was operating in open water, and the shipboard observation is likely biased. SSM/I derived concentrations are consistently lower by as much as 30%. The ice edge was generally delineated quite well with SSM/I throughout the study period.

SSM/I partial concentrations compared quite poorly with shipboard observations. Surprisingly, this tended to be more pronounced deeper into the pack, with differences of up to 75%. The NIC hybrid algorithm [6] did not perform well – most likely because of the presence of multi-year ice in regions that used thin ice tie-points.

IV. CONCLUSIONS

SAR-derived sea ice concentrations using a constant backscatter threshold compared quite well with shipboard ground-truth observations in the Barents sea marginal ice zone, although simple automated ice-type classification is not possible outside of the deeper pack-ice regime. Even within the deeper pack, NIC ice charts probably overestimated the fraction of multi-year ice (Ice charts indicated 80% multi-year for October, whereas limited shipboard and airborne observations indicate it is less than 50% over fairly large areas). Near the ice edge, visual clues such as floe brightness can sometimes fool even experienced analysts. While, SSM/I may aid in ice type identification for areas with a homogeneous ice cover, it can be misleading near the ice edge. These results indicate that for the most accurate analyses, careful monitoring of ice motion and evolution is required.

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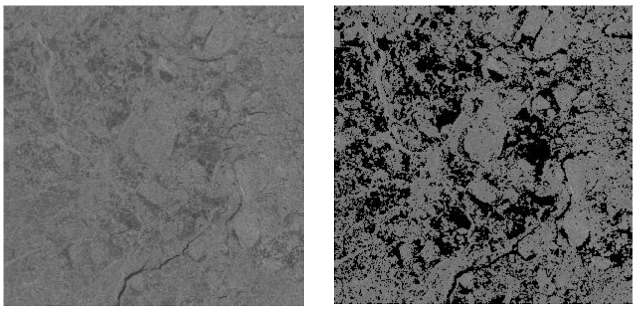

Fig. 1. Radarsat subscene (left) and segmented image (right) for an area 100 km from the ice edge north of Svalbard. Large floes can be discriminated easily, but smaller, rough edged floes are harder to distinguish. Scene is 50 km on a side

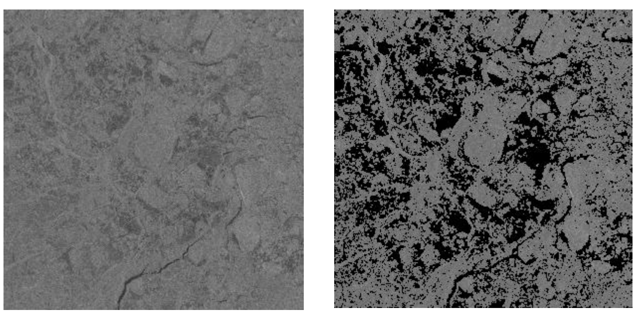

Fig. 2. Subscenes of an area of floes of near uniform brightness. Ice charts produced at the NIC indicated mostly multi-year ice in this area, though it is most likely to have been predominantly new and young ice.

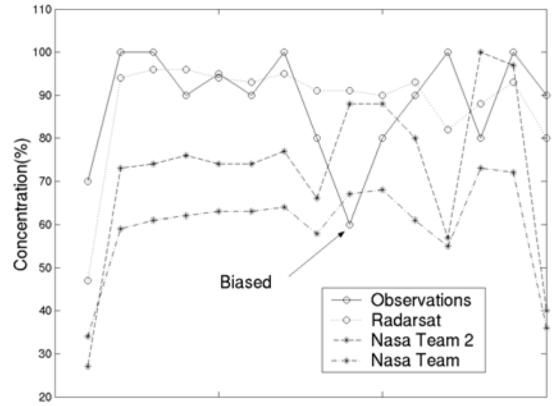

Fig. 3. Comparison of ice concentrations from shipboard observations, SAR analysis, and two passive microwave algorithms. The observation indicated as biased is likely too low as the only observations made during RADARSAT coverage were while the ship was in an open water area.